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Project Mercury

In accordance with the custom of making the results of the United States geophysics and space-research efforts available to scientists throughout the world, a conference was held in Washington, D. C., on June 6, 1961, to report fully on the Mercury suborbital manned space flight of May 5, 1961. The conference was held under the auspices of the National Aeronautics and Space Administration, with the cooperation of the National Institutes of Health and the National Academy of Sciences.

Published proceedings of the conference, entitled Results of the First U. S. Manned Suborbital Space Flight, *served as a basis for much of the following report.*

A major event in the United States program to achieve manned exploration of interplanetary space took place on the morning of May 5, 1961, with the successful suborbital flight of Astronaut Alan B. Shepard, Jr., in a Mercury Spacecraft. (The more-recent flight of Astronaut Grissom is summarized separately on page 20.)

Part of Project Mercury, the National

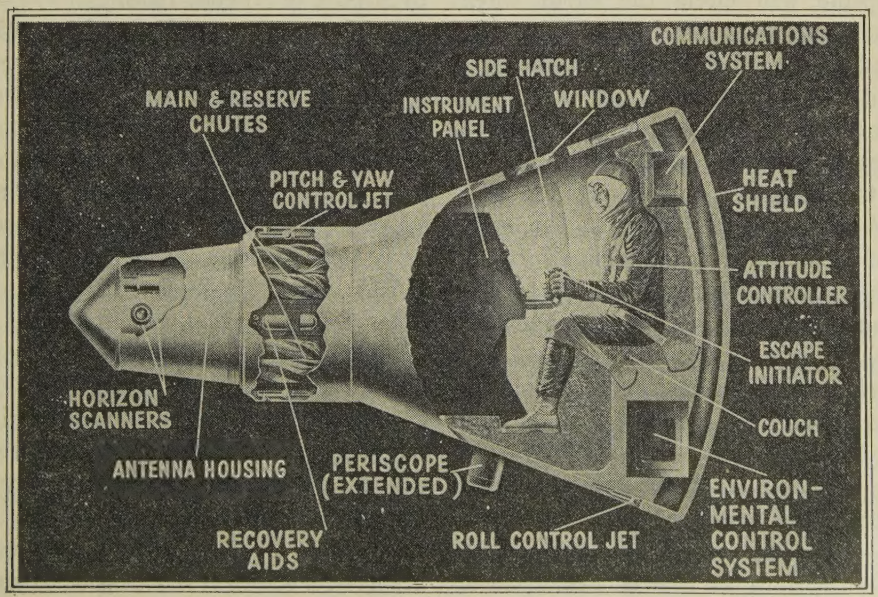

Fig. 1. Manned Mercury Spacecraft (with cutaway view of interior). NASA photograph.

Aeronautics and Space Administration's initial effort toward manned space exploration, the flight began at 9:34 am EST, when the space capsule with the astronaut aboard (Fig. 1) was launched from Cape Canaveral, Florida, by a modified Redstone rocket vehicle. Approximately 15 minutes later—after following a ballistic path (Fig. 2) carrying 302 statute miles downrange, reaching a peak altitude of 116½ statute miles above the earth, and achieving a maximum speed in excess of 5000 mph—the capsule and its occupant parachuted safely into the sea near the Bahama Islands, where they were recovered by a US Marine Corps helicopter of the Mercury Recovery Forces.

Astronaut Shepard bore the flight's stresses with no ill effects, maintained voice communication with the ground throughout the flight, and performed manual tasks involving control of the capsule prior to and during re-entry into the earth's denser atmosphere.

Project Mercury is a national effort of the United States, and is administered by the NASA Space Task Group, at Hampton, Virginia. Practical objectives are (1) to put a manned space capsule into orbit—the orbital capsule will circle the earth three times at altitudes between 100 and 150 miles and at speeds exceeding 17,000 mph in a flight lasting approximately 4½ hours; (2) to investigate man's ability to survive and function in a true space environment; and (3) to recover the capsule and the man safely. A possible extension, in the near future, of the manned-space-flight effort begun with Project Mercury may be an 18-revolution orbital flight lasting about 27 hours.

The primary objectives of the Mercury-Redstone ballistic test flight (designated MR-3) of May 5, 1961, carrying Astronaut Shepard, included (i) familiarizing a man with a brief but complete space-flight experience—lift-off, powered flight, weightless flight, re-entry into the heavier atmosphere, and landing; (ii) evaluating man's ability to perform useful space-flight functions—i.e., manual control of the spacecraft attitude before, during, and after firing of the retro-rockets that slow the capsule for re-entry, and maintaining voice communication with the ground; and (iii) studying man's physiological reactions during space flight. Added to these were the general objectives of continued testing of the Mercury spacecraft and its numerous systems, and of providing training for ground support and recovery forces.

History of Project Mercury

During 1956-58, NACA (the National Advisory Committee for Aeronautics, predecessor of NASA) and the military services conducted studies of the possible use of ballistic rocket boosters to provide the necessary velocities and altitudes for manned orbital and space flight. A NACA working committee concluded in March 1958 that ballistic-entry vehicles launched with existing long-range rockets should be used for the first manned US satellite, and details of a vehicle were drafted. Primary responsibility for research and development of a manned satellite program was assigned to NACA in August 1958.

In September and October 1958, the Joint Manned-Satellite Panel, established by NACA and the Advanced Research Projects Agency (ARPA) of the Department of Defense, formulated specific plans for a program of research leading to manned space flight. These plans were approved in early October 1958 by the Administrator of NASA, which superseded NACA as of October 1, 1958, and by the Director of ARPA. The NASA Space Task Group, composed of personnel from the NASA Langley (Virginia) and Lewis (Ohio) laboratories, and directed by Robert R. Gilruth, immediately began research on Project Mercury at the Langley Research Center.

Since its inception, Project Mercury has involved a wide variety of ground and flight tests, engineering problems, and operational

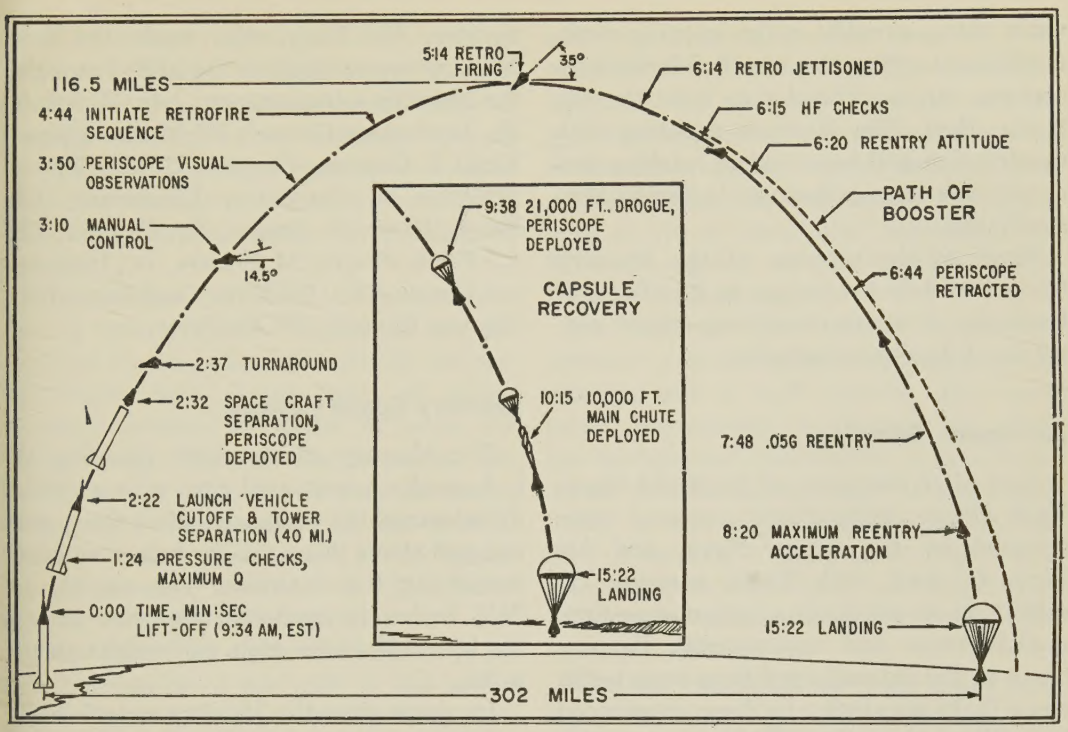

Fig. 2. Trajectory and Flight Profile of MR-3 Flight Carrying Astronaut Alan B. Shepard, Jr. Inset shows deployment of drogue and main parachutes. Relation of event times to points along flight path is only approximate. Adapted from NASA diagrams.

planning. There have been hundreds of wind-tunnel and aircraft drop tests; ten major rocket launches have been made; and specially modified rocket boosters have been put into production. The Mercury spacecraft, contracted to McDonnell Aircraft Corporation, has gone through the entire process of design, engineering, production, and test, and 12 capsules have been completed and delivered. Seven astronauts were chosen for the project after an intensive and stringent selection process; the astronauts and the operating forces have been trained, and a worldwide network of communications and tracking stations is in the final phase of construction.

Extensive support for Mercury has been given by the Department of Defense. From the large military pool of experienced aeronautical-engineering test pilots, NASA selected its seven astronauts. The Army, Navy, and Air Force are supplying valuable medical services and supporting personnel. Each of the Services is providing communications and tracking equipment as well as facilities for sections of the Mercury network.

The Air Force Space Systems Command also supplies Atlas rocket boosters and launch services, air rescue units, map-making and charting, aircraft for astronaut flight and zero-G (weightlessness) training, use of the Atlantic Missile Range, and animal specimens for the space-flight test program.

The Army is furnishing a tracking base at its White Sands Missile Range and amphibious vehicles for recovery needs near the launch site. The Redstone rocket, originally developed by the Army and now produced by NASA and private industry, is the prime launcher for Mercury suborbital flights, such as the MR-3 test.

The Navy, whose main responsibility is location, recovery, and delivery of the capsule and astronaut following flight, pro-

vides ships, aircraft, early warning craft, amphibious and service vessels, Marine helicopters, and associated gear from the Atlantic Fleet. The Navy is assisting with construction and operation of tracking and communications stations on its Pacific Missile Range.

Much of the progress of the Mercury Project to date is also due to the efforts of hundreds of contractors from many segments of American industry.

Astronaut Selection

Soon after formation of the NASA Space Task Group, aeromedical personnel were assigned by the Army, Navy, and Air Force to work with NASA personnel in setting up an astronaut selection procedure, qualifications, and requirements. Because many of the unusual conditions expected in space flight are similar to those experienced by military test pilots, NASA went to this field for volunteers for the astronaut program.

The general requirements were: possession of a bachelor's degree or the equivalent in engineering or the physical sciences; graduation from a military test-pilot school; 1500 hours of jet flying time; under age 40; and five feet, 11 inches, or less, in height. The educational requirement was included because a great variety of scientific and technical problems were expected to confront the astronauts throughout the program.

Of an initial group of 110 potential astronauts, about 90 volunteered for the program. A careful screening based on motivation, experience, and technical background left 32 for further, more-intensive screening. Exacting physical tests and careful assessment for psychological and stress tolerance resulted in final selection of seven Mercury astronauts to undergo preparation for space flight. They entered a training program at the Langley Research Center in early April 1959.

In addition to Alan B. Shepard, Jr., Commander, US Navy, who made the first Mercury space flight in the MR-3 capsule, the Mercury astronauts are: John H. Glenn, Jr., Lieutenant Colonel, US Marine Corps; Virgil I. Grissom, Captain, US Air Force; Malcolm S. Carpenter, Lieutenant, US Navy; Leroy G. Cooper, Jr., Captain, US Air Force; Walter M. Schirra, Jr., Lieutenant Commander, US Navy; and Donald K. Slayton, Captain, US Air Force.

Mercury Space Capsule

The Mercury space vehicle (see Fig. 1) is basically a truncated cone with a cylindrical parachute compartment at the upper end and above this a smaller truncated cone containing the antennas. The capsule is 74½ inches in maximum diameter across the base, 108 inches high, and weighs about a ton.

Its shape gives the Mercury capsule high aerodynamic drag, to slow it rapidly on re-entry, and static stability during portions of its flight path within the atmosphere. It is designed with an extremely blunt leading face covered with a heat shield, permitting it to withstand any known combination of acceleration, heat loads, and aerodynamic forces of launch or re-entry. The heat shield used for ballistic flights such as MR-3 is made of beryllium, and the shield for the higher-velocity, orbital flights is made of ablating fiberglass.

Pilot's Couch and Position in Vehicle: Each astronaut has a couch contoured to his specific body shape. The couches are constructed of crushable honeycomb material bonded to a fiberglass shell and lined with rubber padding. They are designed to support the pilot's body loads during all phases of the flight.

The position of the astronaut in the capsule—with back and lower legs parallel to the base and thus perpendicular to the direction of motion during acceleration and deceleration—minimizes the effects of G-forces on the body, and in particular on the circulatory system. In other body positions,

great hydrostatic pressures during powered flight and re-entry would deprive the brain of blood or force excessive amounts into it, possibly causing serious damage. (One G is equivalent to the acceleration due to gravity at sea level and represents a force on a body equal to the sea-level weight of the body.)

Environmental Control: The environmental control system consists of two individual circuits—the cabin circuit and the astronaut's suit circuit—both of which normally operate for about 28 hours, simultaneously. The suit circuit can be isolated from the cabin circuit when the astronaut closes the faceplate of his helmet. Unless a failure in the cabin circuit causes loss of pressure, however, the pilot's pressure suit will not be inflated.

Plans called for cabin temperature to be held between 80° F and 100° F, and in the MR-3 flight it ranged from 93° F to 111° F, the latter during re-entry heating. Shepard's suit temperature rose from 71° F at launch to 90° F at landing. The spacecraft cabin and the astronaut's pressure suit are provided with a 100% oxygen environment to furnish breathing, ventilation, and pressurization gas required during the flight. The system is completely automatic, but in an emergency, manual controls can be used by the astronaut.

Instruments: The Mercury spacecraft contains a main instrument panel, a left console, and a right console. The main panel, immediately in front of the pilot, has navigational instruments in its left and center sections; the periscope is located directly in the center, affording maximum ease of viewing. Making up the right-hand section are environmental- and communication-system indicators and controls, and electrical switches.

The left console includes sequencing telelights and warning panel, indicators and controls for the spacecraft's automatic pilot,

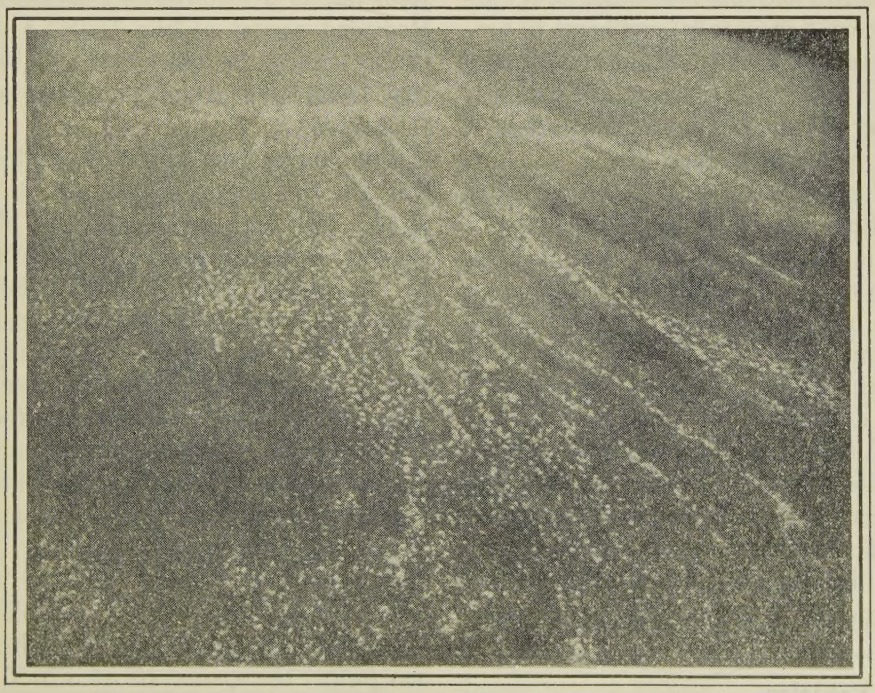

Fig. 3. View from MR-3 Spacecraft Near Peak of Trajectory. Astronaut's periscope view was similar to photograph, which looks northward toward Cape Hatteras and shows cloud cover over coastal regions of Southeast United States. Shepard was able to identify Lake Okeechobee, Florida; Andros Island, in the Bahamas; and some reefs. NASA photograph.

environmental control, and landing systems.

The earth periscope provides a 360° view of the horizon, and the pilot may adjust it manually for low or high magnification. On "low," he has a view of the earth about 1600 miles in diameter (Figure 3 is a photograph from the capsule corresponding to the periscope view seen by Shepard near the peak of the MR-3 flight); on "high," the field of view is reduced to about 80 miles across. The periscope also serves as a navigational aid, and altitudes can be measured by it to within ±10 nautical miles.

A 16-mm camera to the left of the astronaut's head photographs the instrument panel from launch through recovery, and another camera mounted in the main instrument panel observes the pilot throughout the flight.

Pilot communication with the ground is effected by high- and ultra-high-frequency radios and, if needed, a command receiver and telegraph-type code key. The main battery system consists of three 3000-watt-hour batteries and one 1500-watt-hour battery connected in parallel, sufficient to provide power for the entire MR-3 mission and a 16-hour post-landing period, if necessary. A standby power system of 1500-watt-hour capacity provides backup.

The clock in the spacecraft shows both elapsed-time and "seconds from launch," and has a time-delay relay that initiates the retro-rocket firing sequence. The capsule also has a barometer altimeter with a range from sea level to 100,000 feet; reference marks on the dial face indicate altitudes of deployment of the drogue (21,000 feet) and main parachutes (10,000 feet).

The pilot's physical condition is monitored throughout the flight; respiration rate and depth, electrocardiogram, and body temperature information are telemetered to flight surgeons on the ground.

Launch Vehicles

Since various segments of the Mercury operations could be tested by either smaller or larger boosters, depending on the specific need, three basic vehicles of different range and capability were chosen—the Little Joe, the Redstone, and the Atlas.

The *Little Joe* is made up of a cluster of eight solid-propellant rockets housed in a cylindrical section. Developing a total thrust of about 250,000 lbs at launch, it can propel a full-scale Mercury capsule at speeds up to about 4000 mph over ranges to about 130 miles.

The Little Joe has been used primarily in tests of the escape system and of capsule-booster matching. Six successful Little Joe launches have been made in tests covering a variety of altitude and velocity conditions. Early launches involved "boilerplate" versions of the capsule; later launches used actual capsules, and rhesus monkeys were carried on two flights.

The *Redstone* vehicle was intended for use in higher and longer-range ballistic qualification tests and in the first astronaut-piloted suborbital flights. The Mercury-Redstone is a modification of the reliable Redstone rocket of the U. S. Army, an earlier version of which put into orbit the first United States artificial earth satellite —Explorer I.

Standing 83 feet high and weighing 66,000 lbs, the rocket generates a thrust of 78,000 lbs and can propel the Mercury capsule at speeds greater than 5000 mph. In an earlier test, a Redstone-boosted capsule carried a chimpanzee passenger ("Ham") to an altitude of over 155 miles and a distance of nearly 420 miles downrange. It is planned to follow the Redstone-boosted flight of Astronaut Shepard with further manned Mercury-Redstone ballistic flights before orbital flight is attempted.

The *Atlas,* the largest Mercury booster, is intended for the final goal of manned orbital flight. The Atlas is capable of developing about 380,000 pounds of thrust and can propel the spacecraft at orbital speeds of over 17,000 mph and to apogee altitudes up to about 150 miles.

One successful Mercury test launch has

been made using the Atlas booster. In this test of the effect on the capsule of maximum heating at high re-entry speeds, the capsule reached a peak altitude of about 107 miles and a maximum velocity of approximately 13,000 mph.

Escape System

The possibility of an unplanned, emergency termination, or "abort," of the Mercury flight mission was provided for by inclusion of an escape rocket mounted on a tower above the spacecraft (Fig. 4). The escape system can be triggered by either automatic or manual means. In addition, an elevating boom, known as the "cherry picker," can remove the pilot from the capsule if an emergency arises during the final 90 minutes of countdown.

Once the launch vehicle has received its firing signal, and before it has lifted off the pad, automatic failure-detecting systems built into the vehicle would sense any impending trouble and initiate an abort. When this happens, the spacecraft is released from the launch vehicle and the escape rocket is fired, pulling the capsule to an altitude of over 2000 feet and well to one side of the launching pad. As the spacecraft reaches peak altitude, another small rocket, mounted beneath the escape rocket, carries the escape rocket and tower away from the spacecraft to clear the way for deployment of the craft's parachutes.

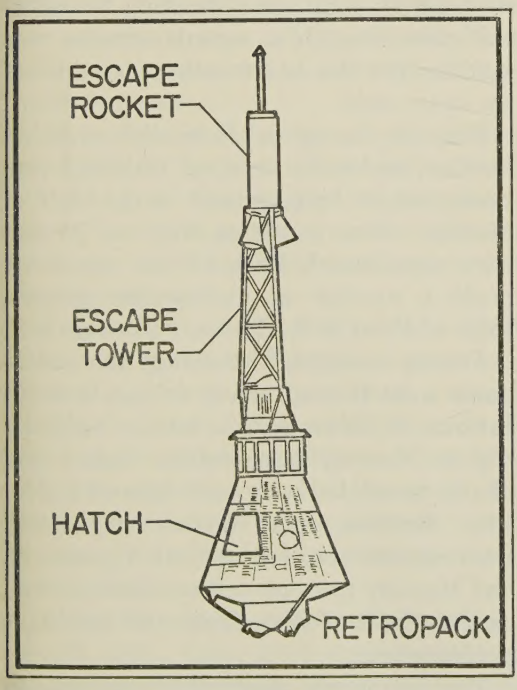

Fig. 4. Escape Tower and Rocket Mounted Above Mercury Capsule. The retro-rockets are used to carry capsule away from launch vehicle in "aborts" occurring during interval between separation of escape system and cut-off of booster engines. NASA drawing.

The six-foot drogue parachute opens first, stopping any oscillations of the capsule, pulling away the antenna canister, and deploying the 63-foot main landing parachute. The heat shield is then released, extending the landing-impact bag, which forms a pneumatic cushion to absorb the shock of landing. Though the impact bag is primarily for impacts on land, it is also required for water landings when wind and waves are high.

For impending booster malfunctions after lift-off and before normal separation of the escape system, the same sequence would be followed. In the interval between separation of the escape system and cut-off of the booster engine, the spacecraft can be separated from the booster automatically or manually by firing the posigrade rockets on the base of the craft.

The escape system can also be triggered, if necessary, by radio command from the blockhouse, by the Mercury Control Center, or by the range safety officer at the Central Control Building of the Atlantic Missile Range.

Training Program

The astronaut training program was broken down into six general areas, as follows:

(1) Education in the basic sciences—astronomy, meteorology, astrophysics, and geography, including techniques for making

scientific observations in these areas; in astronautics—particularly in various aspects of rocketry; in basic aviation medicine and orbital flight hygiene; and in the space environment.

(2) Familiarization with the conditions of space flight—heat, pressure, G-force levels, and other special conditions of space flight; this phase of training included periodic simulated flights in centrifuges and pressure chambers, weightless flying, training in human disorientation devices, and participation in the development of techniques to minimize the effects of vertigo. A major aim of this part of the training program was also to provide data on the astronauts' ability to contribute to system reliability under flight conditions; on psychological and physiological effects of both normal and emergency flight conditions; and on requirements for support and restraint, environmental control, and crew-space layout.

(3) Training in the operation and maintenance of the Mercury space capsule, with particular emphasis on scientific instruments and life-support equipment.

(4) Participation in the vehicle development program; to make use of the engineering backgrounds of the astronauts, and to familiarize them further with the project's technical aspects, each pilot has been assigned a specialty area in the Mercury development program, and thus acquires specialized knowledge that is shared with the entire group. The specialty areas are as follows:

Carpenter—Communications equipment and procedures, periscope operation, and navigational aids and procedures.

Cooper—Redstone booster, including configuration, trajectory, aerodynamics, countdown, and flight procedures.

Glenn—Cockpit layout and configuration, instrumenation, and controls for capsule and for simulation equipment.

Grissom—Reaction control system, hand controller, autopilot, and horizon scanners.

Schirra—Environmental control systems, pilot support and restraint, pressure suit, and aeromedical monitoring.

Shepard—Recovery systems and procedures, parachutes, and range network.

Slayton—Atlas booster and escape system, including Atlas configuration, trajectory, aerodynamics, countdown, and flight procedures.

(5) Aviation flight training; to maintain the astronauts' proficiency in high-performance aircraft, two jet fighter aircraft were assigned to them, and they receive annual instrument checks in jet trainers of the Tactical Air Command. This program provides the astronauts with additional altitude acclimatization, instrument flight training, and physiological conditioning for high-altitude, high-speed flight.

(6) Integration with ground-support and launch-crew operation, to give the astronauts complete knowledge of the launch phase of Mercury flights.

Among the many specific Mercury training activities was concentrated personal instruction in celestial navigation and star recognition; a trainer simulating the celestial view through a capsule window was used for practice in correcting yaw-drift of the spacecraft.

Practice in egress from the capsule's hatches, and water survival training, were conducted at Langley and in the Gulf of Mexico, where swells as high as 10 feet were experienced. Each of the astronauts made a number of underwater egresses, some of them in the Mercury pressure suit.

During centrifuge training, the astronauts went through many full-scale simulations of Mercury-Redstone ballistic flights, Mercury-Atlas orbital flights, and aborts associated with each type of trajectory. Environmental factors emphasized were acceleration, reduced cabin pressures, and Mercury pressure-suit condition, as well as the effects of these factors on astronaut performance.

The astronauts received familiarization with weightlessness by being flown through parabolic trajectories in aircraft. The weightless intervals varied from 15 seconds to a minute, and there were 3 to 24 such intervals per flight. Each astronaut ex-

perienced approximately 40 minutes of weightlessness in all. During these flights, data were collected on the astronauts' ability to perform a simple tracking task, on changes in normal speech, on experience in eating and drinking, on visual-acuity and visual-orientation problems of various body positions, and on post-weightless psychomotor testing.

Extensive training was received in the Air Lubricated Free Axis Trainer, using a periscope display or a window with a simulated earth horizon for controlling capsule attitudes, etc., during orbit and retro-rocket firing. The astronauts also received training in the multiple-axes space-test inertia facility at the NASA Lewis Research Center, for (i) familiarization with physiological and psychological effects of tumbling, and (ii) practice in recovery from tumbling when it occurs. A slow build-up of axes and rates was used, to a maximum of 30 rpm while rotating about all three axes. In all cases, the astronauts were able to stop tumbling relatively quickly using a rate indicator and hand controller.

The astronauts also have had extensive experience in the Mercury pressure suit. In the past year, almost all training in centrifuge, procedures, egress, environmental control, and weightless flight has incorporated the pressure suit.

Preparation for the MR-3 Flight: Pilot rehearsals for the MR-3 mission were conducted vigorously for more than a month before the launch, using actual flight hardware under realistic conditions. Many mission simulations were held in which the Mercury pilot "flew" his spacecraft within a specially designed altitude chamber or in a centrifuge.

About two weeks before the scheduled launch date, three days were devoted to conducting realistic countdowns and simulated flights at the launch site, with the pilot, in full-pressure suit, inside the spacecraft in the nose of the Redstone rocket. In the first two of these simulations, the gantry remained in position against the vehicle and the side hatch of the spacecraft was left open. In the third, the side hatch was secured, the pilot's cabin purged with oxygen, and the gantry moved away.

During the four days preceding launch, the MR-3 mission was rehearsed repeatedly, both in the vehicle itself and in a spacecraft simulator (the Mercury Procedures Trainer) in the Mercury Control Center.

Astronaut's Tasks during MR-3 Flight

To determine man's ability to function in space—the astronaut was given several definite tasks to perform during the flight. He also was expected to describe action he was taking, events as they unfolded, and what he saw during his control of the spacecraft. The following review of the MR-3 flight sequence (see Fig. 2) provides an outline of the astronaut's duties:

Thirty seconds after lift-off and at approximately equal intervals during powered flight, Shepard reported on his control-system fuel supply, the G-load he experienced, pitch angle of the capsule, cabin pressure, and his oxygen supply. (Figure 5 charts the G forces experienced during the flight.) He then monitored and reported cut-off of the booster engines and separation of the escape system, 2 minutes 22 seconds after launch and at an altitude of about 196,000

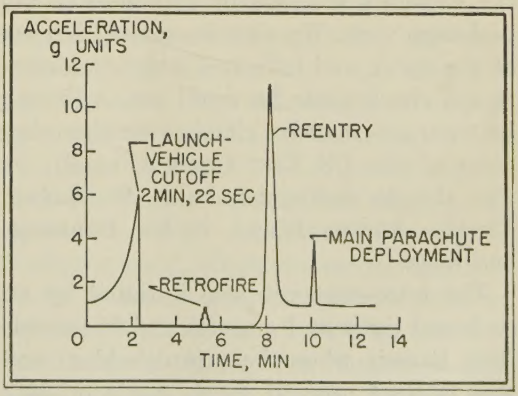

Fig. 5. Acceleration Profile of MR-3 flight. Magnitudes and times of G-force experienced by astronaut are shown. NASA diagram.

feet. At this time, the spacecraft had reached its maximum velocity of about 4500 mph with respect to the earth (ground speed) or 5180 mph relative to the solar system (inertial velocity).

About 2½ minutes after launch, a cluster of three small posigrade rockets was fired, pushing the capsule up and away from the booster. After oscillations generated by separation were corrected by the automatic pilot, the periscope was extended several inches into space. These events were reported by Shepard, and about 15 seconds after engine cut-off he announced the beginning of the spacecraft's automatically controlled 180° turn into its blunt-end-forward re-entry position.

Three minutes and 10 seconds from launch, the pilot manipulated the control stick, with his right hand, through a sequence of "dry run" yaw, pitch, and roll maneuvers. The results of this test of the pilot's ability to perform while weightless—a condition that lasted for 5 minutes and 4 seconds, through the highest portion of the trajectory—were simultaneously telemetered to the ground for analysis. Shepard then took actual control of the capsule's attitude, maneuvering it through up to 20° of pitch, yaw, and roll, in that order.

Almost 4 minutes from lift-off, and near peak altitude, Shepard began to use his periscope as a navigational aid, controlling the capsule's attitude by reference to the periscope view. He also described his view of the earth, and indicated which predetermined checkpoints he could see. Although he reported extensive cloud cover obscuring most of the US East Coast (Fig. 3), he was able to distinguish Lake Okeechobee, Florida, Andros Island, in the Bahamas, and reefs.

The retro-sequence was initiated by an on-board timer at 4 minutes and 44 seconds from launch, when the capsule's blunt end was pitched upward to an angle of 34°; yaw and roll were kept at 0°. Twenty-seven seconds later, at the peak of the trajectory, 116½ miles above sea level, three powerful solid-propellant rockets on the blunt face of the craft "ripple-fired," each burning for about 10 seconds at overlapping five-second intervals. During orbital flights, these rockets will be used to brake the much-greater speed of the craft as it comes back into the atmosphere. On the MR-3 sub-orbital training flight, however, they were fired only for continued qualification of the retro-motors and to provide the pilot with manual retro-fire control experience.

The pilot reported each retro-firing, and, 60 seconds after start of this sequence, he armed the "retro-jettison" switch to release the exhausted retro-rocket package. At 6 minutes and 20 seconds, in response to Shepard's manual control movements, the capsule went into re-entry attitude of 40° with respect to the horizon, and was then switched from manual to automatic control. The periscope was retracted at 6 minutes and 44 seconds.

The astronaut now once again put the capsule through manually controlled pitch, yaw, and roll maneuvers to determine whether he could function as well after more than five minutes of weightlessness as before. Some roll was planned in order to reduce landing dispersion during re-entry, and Shepard induced a roll of 2 rpm. As the craft touched the fringe of the atmosphere, 7 minutes and 48 seconds from lift-off, the astronaut felt the first re-entry G force of .05 G. The re-entry cycle lasted 1½ minutes, reaching a maximum force of 11 G's at 8 minutes 20 seconds (Fig. 5), and at an altitude of about 83,000 feet. During the re-entry cycle, forces greater than 5 G's were experienced for a full half minute.

At approximately 9½ minutes from launch and at an altitude of about 21,000 feet, the six-foot drogue parachute was deployed, and a little over ½ minute later, at 10,000 feet, the main parachute unfurled. The astronaut observed these operations through the periscope.

The capsule then descended at about 32 feet per second (roughly 20 mph) and landed on the sea surface at 9:49 am EST,

15 minutes and 22 seconds after lift-off. The impact point was within three miles of the previously calculated probable landing point, 80 miles ENE of Grand Bahama Island. The Redstone booster had already struck the water some 22 miles farther downrange.

Recovery Operations

Within five minutes of impact with the water, U. S. Marine helicopters had picked up Astronaut Shepard and his MR-3 spacecraft and were on the way back to their carrier, the *USS Lake Champlain.* The astronaut was landed on the ship's deck at approximately 10:00 am EST, 11 minutes after water impact.

To effect quick recovery of the astronaut and space craft in all Mercury flights, ships, aircraft, helicopters, and ground vehicles are stationed at (i) Cape Canaveral, to cover a possible abort while a booster is still on the launching pad, or just above it; (ii) in off-shore waters near Cape Canaveral, for an abort during early stages of a flight; (iii) in the expected landing area; and (iv) for suborbital flights, along the entire flight path to a region beyond the expected landing point.

Biomedical Results of MR-3 Flight

A major area of preparation for the MR-3 flight concerned the biomedical readiness of the astronaut and the testing of the life support systems. The biomedical preparation of the Mercury astronauts had two aspects: (1) an extensive course of instruction in the physiology of their body systems, to give the astronauts an understanding of the effects on them of flight stresses and to enable them to report better on these effects, and (2) a complete program of testing and training in the dynamics of the flight, with repetitive experiences under simulated flight conditions.

While the astronaut training program was progressing, a parallel program using animals for qualification of the support system was begun and carried through. This program, reached its culmination with the MR-2 flight in January 1961 carrying the chimpanzee, Ham. The chimpanzee bore the flight stresses well and continued to perform on the psychomotor apparatus throughout, except during the above-nominal accelerations associated with firing of the escape tower and re-entry. As the flight profile of MR-2 exceeded that expected for MR-3, it was concluded that an astronaut could be carried safely on MR-3.

The astronaut was examined in detail both before and after the MR-3 flight, thus providing both a fitness test prior to launch and a basis for determining any significant changes resulting from stresses of the flight. Preflight physical examinations showed Astronaut Shepard to be relaxed, cheerful, and in good health, with all findings consistent with those of previous examinations. Psychiatric examination indicated he was alert and had abundant energy and enthusiasm. He discussed flight hazards realistically and, while he expressed slight apprehension, he dealt with them by repetitive consideration of ways to manage each possible eventuality. All thought was directed toward the flight and no disturbances of intellectual function were observed.

Psychiatric examinations on Grand Bahama Island several hours after lift-off produced the report that Shepard ". . . seemed quietly elated and offered no complaints," and that he ". . . felt calm and self-possessed." The following is an excerpt from another portion of the report: "He was more concerned about performing effectively than about external dangers. He reported moderate apprehension during the preflight period, which was consciously controlled by focusing his thoughts on technical details of his job. As a result, he felt very little anxiety during the immediate prelaunch period. After launch, he was preoccupied with his duties and felt concern only when he fell behind on one of his tasks. There were no unusual sensations regarding

Table 1. Measurements of Vital Physiological Elements of Astronaut Shepard Before and After MR-3 Flight

Vital Physiological Elements	Preflight −8 hr	Postflight	
		Shipboard	+3 hr
Body weight	169 lb 4 oz	167 lb 4 oz	166 lb 4 oz
Temperature, °F	99.0 (rectal)	100.2 (rectal)	98 (oral)
Pulse per min	68	100	76
Respiration per min	16		20
Blood pressure, mm Hg:			
Standing			102/74
Sitting	120/78	130/84	
Supine			100/76
Pulse per min:			
Before exercise	68		76
After exercise	100		112
Time for pulse to return to normal	2¾ min		3 min

weightlessness, isolation, or separation from the earth. Again, no abnormalities of thought or impairment of intellectual functions were noted."

Two post-flight medical examinations revealed no significant changes in the astronaut's condition as a result of the flight. Electrocardiogram, electroencephalogram, and chest X-rays were normal. A number of changes, all expectable and within normal ranges, were noted, however, in body weight, temperature, respiration rate, blood pressure, and pulse rate at rest and before and after exercise; these are shown in Table 1.

The astronaut maintained a pulse rate of about 80 beats per minute during the prelaunch countdown with brief rises to 90-95 during significant spacecraft checkout events. Respiration remained generally between 15 and 20 breaths per minute during this period. As shown in Figure 6, pulse rate rose to 108 about a half minute before lift-off, was 126 at lift-off, and reached a peak of 138 at the time of cut-off of the launch-vehicle engine and spacecraft separation. This rate was sustained for about 45 seconds. The pulse-rate was erratic during the weightless interval, falling to 108 just prior to re-entry. A second peak, of 132, occurred about 30 seconds after maximum re-entry acceleration, and during descent the rate fluctuated between 130 and 108. At loss of signal after impact, it was 111 beats per minute.

The astronaut's respiration rate reached a peak of 40 breaths per minute during the launch and powered phase of the flight (Fig. 6), and fell to 20 per minute near the end of the weightless period. It rose again during re-entry to a high of 30, and fluctuated between 20 and 25 breaths per minute during the descent. Electrocardiogram traces showed no significant abnormalities throughout the countdown and flight; deep body temperature varied from 99° at installation of the pilot into the spacecraft to 99.2° near the end of the flight.

A report by physicians of NASA's Aerospace Medical Branch concludes that: (1) physiological responses of the astronaut were consistent with intact conscious performance during all phases of the MR-3 flight; (2) physiological responses to five minutes of weightless flight (interrupted by 23 seconds of retro-fire) were uneventful; (3) acceleration-weightlessness transition periods produced physiological responses within the limits of intact function, and the relative change in pulse rate in going from weightlessness to re-entry acceleration was comparable to that in going from 1 G to re-

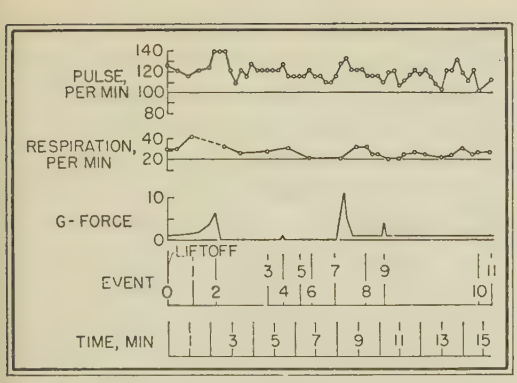

Fig. 6. Astronaut's Pulse and Respiration Variations during MR-3 Flight. Flight time, G-force profile, and major flight events are shown for comparison. Events are as follows: (1) maximum dynamic pressure; (2) launch-vehicle engine cut-off, spacecraft-booster separation, and spacecraft turnaround; (3) orientation to retro-fire attitude; (4) retro-fire; (5) jettison of retro-package; (6) orientation to re-entry attitude; (7) .05 G, at beginning of re-entry into denser atmosphere; (8) opening of drogue parachute; (9) opening of main parachute; (10) impact with water; and (11) loss of telemetry signal. NASA diagram.

entry acceleration on the centrifuge; and (4) special senses—vision, semicircular canal function, and hearing—appeared intact throughout the flight.

Pilot Performance during MR-3 Flight

Four major sources of data were used to evaluate Astronaut Shepard's performance capabilities during the MR-3 flight; they are (i) the astronaut's communications with the ground, (ii) records from the on-board pilot-observer camera, (iii) telemetry records of spacecraft attitude while under manual control, and (iv) the pilot's narrative of his activities as given in the post-flight debriefing.

During the flight, Shepard monitored 27 spacecraft events, communicated with the ground 78 times, made several series of attitude maneuvers, and made observations through the spacecraft periscope and window on several occasions. (See Figure 7)

Study of the pilot-observer-camera record showed that Shepard's attention appeared to have been focused on the appropriate monitoring instruments throughout the mission. His scan pattern was active and there appeared to be no wandering of attention, no fixation, and no illogical concentration on specific instrumentation. There was also no evidence of nystagmus (rapid, involuntary oscillation of the eyeballs).

Analysis of voice communication records indicated that the astronaut made all of the normal reports during launch and re-entry very close to the times of occurrence of the events, and comparisons with telemetered data verified the accuracy of these voice reports. In addition to the standard monitoring reports, Shepard made a number of unscheduled reports of unique events during the flight, responded rapidly to ground communications while weightless, and described clearly his observations through the periscope. The voice communications records confirm the camera observations that the pilot kept up with mission events and remained alert for novel or unprogrammed events throughout the MR-3 flight.

Because the flight path of a space vehicle is independent of attitude unless power is being applied, attitude control in space, except during retro-fire, is less critical than it is for aircraft. Thus, the expenditure of the additional fuel necessary to maintain control within tight limits is not justified.

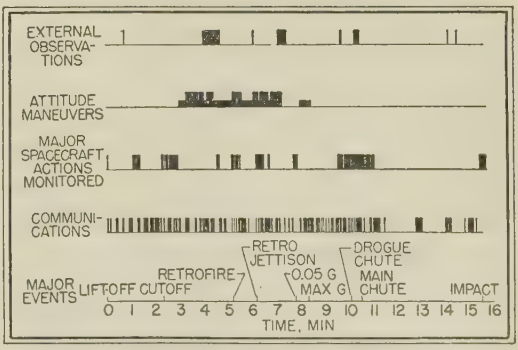

Fig. 7. Astronaut's Activity Schedule during MR-3 Flight. Time from launch and major events are shown for comparison. NASA diagram.

However, in each of the three attitude dimensions used—pitch, yaw, and roll—Shepard almost always kept the craft's attitude within the ranges established on trainer runs. During re-entry, when firing of the retro-rockets produces acceleration disturbances about the vehicle's axis, the pilot held the attitude fairly steady for all three axes of motion and reported that retro-fire misalignment torques felt about the same as in the preflight trainer.

In summary, records from the on-board camera, voice communications, and telemetry monitoring of spacecraft attitude, and substantiated by the astronaut's post-flight narrative, indicate that the pilot successfully met all mission requirements. He monitored all events and instrument readings, reported them accurately, controlled the craft's attitude within normal limits, and reported clearly his observations through the periscope. His performance of these activities during actual flight, moreover, was comparable to that achieved on the procedures trainers operated under optimal environmental conditions.

International Exchange of Geophysical Data

As part of the fundamental international planning for the IGY program, World Data Centers were established to collect data from the numerous and wide-spread IGY observational programs and to make such data readily accessible to interested scientists and scholars for an indefinite period of time. In order to guard against accidental loss of irreplaceable data, and to make access as convenient as might be practical, it was agreed that there be duplicate centers for each IGY discipline in at least two, and for most disciplines, three, places in the world.

The original recommendation to establish the IGY World Data Centers was made in 1955. By the beginning of the IGY, July 1, 1957, the International IGY Committee (Comité Spécial de l'Année Géophysique Internationale, or "CSAGI") had designated specific WDC's from among a number of institutions or IGY national committees, each of which agreed to support a particular WDC actively in accordance with principles determined by CSAGI. Three WDC's were established: World Data Center A, divided by discipline among eleven institutions in the United States; World Data Center B, in three institutions in the USSR; and World Data Center C, in 21 institutions located in eight nations of Western Europe, in Australia, and in Japan.

The understandings regarding the content, mechanism, and schedule of data flow to Data Centers, as well as interchange among centers, were worked out under CSAGI auspices. These understandings were arrived at by specialists in each discipline after considerable analysis and discussion, both in international assemblies and in domestic meetings. The final agreements, which appear in the "Guide to World Data Centres," published in Volume VII of the *IGY Annals*, applied specifically to data taken during the IGY observation period, July 1957—December 1958. By subsequent resolution of CSAGI, they were also applied, with modifications in some disciplines and programs, to data taken during the observational period of "International Geophysical Cooperation—1959" (IGC-1959), January—December 1959.

Responsibilities and Methods of Operation

In addition to the detailed arrangements for data collection in the various disci-

plines, the WDC "Guide" set forth fundamental principles of operation of the WDC's. Each WDC is responsible for (1) endeavoring to collect a complete set of data in the field or discipline for which it is responsible, (2) safekeeping of the incoming data, (3) correct copying and reproduction of data, to maintain adequate standards of clarity and durability, (4) supplying copies to the other WDC's, as needed, and (5) preparing catalogues of all data in its charge.

The WDC's are also required to supply on request (at a cost not to exceed the cost of copying and postage) copies of material collected as part of the international data exchange, and also, by appropriate arrangements, to make this material in the WDC's available to visiting scientific workers. It was subsequently recommended that the WDC's collect reprints of publications on IGY subjects in order that the WDC's might serve as information centers; scientists were urged to cooperate in this endeavor by sending four reprints of all relevant papers to the appropriate WDC, from which they are then forwarded, as needed, to the corresponding WDC-A, B, or C.

Six-Monthly Catalogues: To make known to scientists the holdings of the WDC's and to facilitate interchange among the WDC's, the "Guide" required that catalogues of data in the WDC's be issued semiannually. Throughout the IGY, these catalogues were collated and distributed by the CSAGI Coordinator in Brussels; since 1959, catalogues have been distributed directly by the WDC's. WDC-A has thus prepared seven 6-monthly catalogues, the last four of which (for 1959 and 1960) were published in the WDC-A General Report Series. Each WDC-A catalogue is cumulative. The eighth 6-monthly catalogue (including data received by July 1, 1961) is now in preparation and will be available in August from WDC-A (National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C.) or from any of the subcenters of WDC-A.

WDC-A Report Series: In keeping with the obligation of the WDC's to make data widely available, WDC-A has issued seven series of reports (see *Bulletin No. 44*) containing material of special interest. The General Report Series contains various reports of scientific results as well as catalogues and program descriptions. The remaining six series of reports are issued by the relevant discipline centers of WDC-A: aurora (instrumental), glaciology, oceanography, rockets, satellites, and solar activity. (A booklet entitled "List of IGY Report Series," containing a list of all reports issued by WDC-A, together with brief descriptions of the contents, is available upon request from IGY World Data Center A.)

Future Activities of the Centers

Following the termination of CSAGI, in 1959, responsibility for the World Data Centers was assumed by the Comité Internationale de Géophysique (CIG). The CIG reaffirmed the CSAGI resolution that the WDC's continue to collect data from observations made after the IGY/IGC period, and strongly recommended that data exchange arrangements be subject to periodic review.

The CIG Reporters were called upon to seek the advice of the relevant scientific unions in order to assure (i) that arrangements for future data interchange would be responsive to the changing needs and interests of scientific specialists and (ii) that a revised "Guide to WDC's" would be issued. In view of the formulation of plans for the Year of the Quiet Sun, 1964-65 (IQSY; see *Bulletin No. 48*), CIG recommended that the revised "Guide" be issued for 1960-63, and that another review be made for the IQSY period.

As for completion of the IGY/IGC data interchange: In January, 1961, the CIG resolved that IGY/IGC data collection be officially terminated by December 1, 1961, at which time the final catalogue of IGY/IGC data should be prepared for publication in the *IGY Annals*. CIG also called

upon the appropriate CIG Reporters to evolve, with the help of international unions, the most suitable format for the final catalogue.

Geophysics Research Board's Panel on Data Exchange

The US National Academy of Sciences has established a Geophysics Research Board (see *Bulletin No. 48*) to serve as the national counterpart of the CIG; under the GRB, a Panel on International Exchange of Geophysical Data was established to make recommendations to GRB regarding data-exchange problems facing the CIG. At present, the Panel has three tasks: (i) completion of IGY/IGC data exchange; (ii) data exchange during the period 1960-63; (iii) data exchange during IQSY.

Although primary responsibility for the World data Centers lies with CIG, the CIG, in turn, and its US counterpart organization, the GRB, recognize the responsibility of other committees of the International Council of Scientific Unions (ICSU) in certain scientific areas, as follows: the Committee on Space Research (COSPAR), and the corresponding Space Science Board (SSB) of the US National Academy of Sciences; the Special Committee on Oceanographic Research (SCOR), and the Academy's Committee on Oceanography; and the Special Committee for Antarctic Research (SCAR), and the Academy's Committee on Polar Research. In evolving recommendations for future data exchange, the GRB's Panel on data exchange accordingly looks to these various US national committees and to the GRB Panels on the IQSY, the World Magnetic Survey, and the Upper Mantle Project, for recommendations in the relevant disciplines.

At the present time, the GRB's data-exchange Panel is conducting a review of data exchange arrangements for the current period. The Panel has made a survey of scientists in all geophysical disciplines in order to ensure that data collection requirements are reasonable and useful in the light of experience gained through the IGY and of rapidly changing interests in various scientific disciplines. In general, it is felt that the intensive data collection that characterized the IGY should be relaxed in order to relieve scientists of some of the burden of preparing data for the WDC's and to reflect the post-IGY decrease in observational efforts.

The Panel has also inquired of some 500 researchers who have used data from World Data Center A—many of them had consulted the archives of the Data Centers directly—to discover what research had been made possible by the availability of data in the WDC's, and what publications had resulted from these researches. The response to this inquiry indicates that a considerable number of important researches have been based almost solely on material in the WDC's, and a much larger number of published papers have been based in part at least on IGY data. At the same time, many of these researchers expressed doubt that the scientific community was generally aware of the wealth of information available in the WDC's.

The sentiment of the responses was quite unequivocally in favor of continued operation of the Data Centers, and many contained pertinent recommendations for future activities of the WDC's. In view of this response, the GRB has strongly recommended that the World Data Centers be continued in their present form at least until mid-1962, by which time precise national and international recommendations should have been formulated into a new "Guide" setting forth the activities and responsibilities of the World Data Centers in the coming years.

Antarctic Notes

NSF Office of Antarctic Programs

An Office of Antarctic Programs has been established within the National Science Foundation to replace the Antarctic Research Program, formerly a part of the Foundation's Office of Special International Programs.

Thomas O. Jones, who was NSF's Antarctic Program Director, has been appointed Head of the Office of Antarctic Programs and Albert P. Crary has been appointed Chief Scientist. Crary, who will also serve as Science Adviser on Antarctica to the Director of NSF, Alan T. Waterman, was Chief Scientist of the NSF Antarctic Research Program, and, prior to that, Deputy Chief Scientist of the US-IGY Antarctic Program.

The Office of Antarctic Programs has responsibility for the United States Antarctic Research Program (USARP), which includes all US scientific work in Antarctica. USARP scientists from colleges, universities, and Government agencies, working under NSF sponsorship, carry out research in biology, geodesy and cartography, geology, glaciology, meteorology, oceanography, upper-atmosphere physics, and seismology.

During the past 2½ years, the scope of scientific activity in the Antarctic has steadily increased. Many IGY investigations have been continued, particularly in meteorology and geophysics, and other fruitful fields of research have been encouraged. Extensive work is now being carried out on the geology of the continent and on the life forms found on the ice and in the surrounding oceans. Mapping activity has been greatly expanded, and oceanographic work in Antarctic waters has been increased. Beginning in the fall of 1961, the oceanographic research ship USNS *Eltanin,* operated by the Military Sea Transportation Service, will be used for NSF research programs in the oceans of the high southern latitudes.

New institutions have been brought into the work, and projects by individual investigators or teams working on specific problems have been encouraged. During the past year, for the first time, such projects received the largest proportion of the funds available for scientific work in Antarctica.

Major Antarctic research programs are maintained by the University of Wisconsin, the US Weather Bureau, Ohio State University, the US Geological Survey, Stanford University, the US Coast and Geodetic Survey, Bartol Research Foundation, the American Geographical Society, and the University of Michigan.

The Office of Antarctic Programs operates within a framework established by Bureau of the Budget Circular A-51, 1960, "Planning and conduct of the United States program for Antarctica." By that document, NSF was given responsibility to continue to exercise the principal coordinating and management role in developing and carrying out an integrated US scientific program for Antarctica. The Foundation, in consultation with the Department of State, also arranges for cooperative scientific programs with other nations participating in Antarctic research.

The Foundation looks to the Committee on Polar Research of the National Academy of Sciences-National Research Council for recommendations concerning proposed scientific programs in Antarctica. The United States Navy provides logistics support for scientific projects at US Antarctic stations.

Magnetic Declinations Obtained on Traverses in West Antarctica

In a letter to the *Journal of Geophysical Research,* April 1961, N. A. Ostenso and C. R. Bentley, of the Geophysical and Polar Research Center, University of Wisconsin, report on magnetic declinations in West Antarctica and on the Ross and Filchner

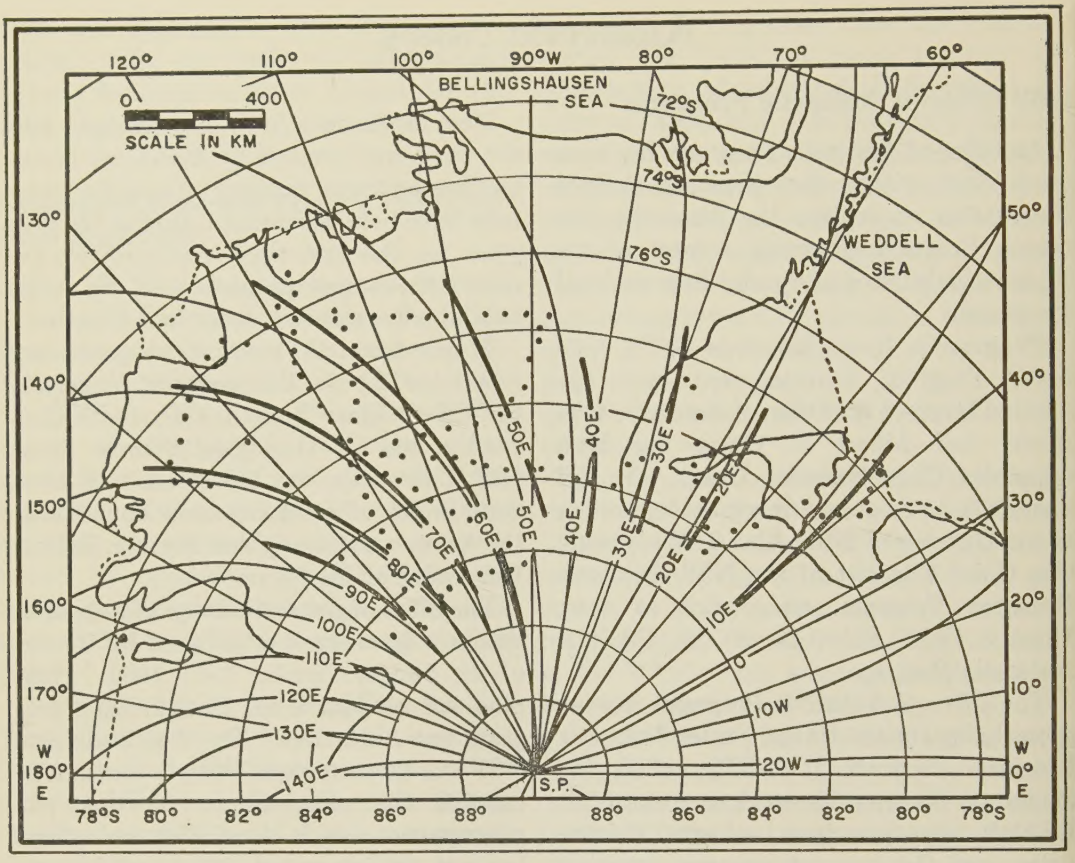

Fig. 8. Magnetic Declinations in West Antarctica. Light lines are isogonic lines from US Navy Hydrographic Office Map No. 1706S (1960); heavy lines are based on IGY traverse and station observations (dots). Redrawn from map by Ostenso and Bentley.

Ice Shelves. The declination observations were made during the course of six oversnow traverses and one airborne traverse conducted over the past four austral summers by US scientific teams.

Declination observations were made at intervals of 30-36 nautical miles on the oversnow traverses and at all stations of the airborne traverse, using either a Dietzgen transit or a tripod-mounted surveying compass. The magnetic azimuth of the center of the sun was compared with the true azimuth for the time of the measurement. The maximum error in absolute declination resulting from temporal magnetic variations is 1.0° for the transit observations and 1.5° for the surveying compass observations.

Figure 8 shows the locations of the observation stations, and contains isogonic lines (lines of equal magnetic declination) based on data obtained at these stations. Comparison of these isogonic lines resulting from field observations with computed isogonic lines from US Navy Hydrographic Office map 1706S (1960) shows a very close correlation. The small discrepancy may be partly explained by secular variations during the three-year period of observation, a higher-than-normal magnetic susceptibility in western West Antarctica owing to its largely volcanic composition, or both.

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Note on the MR-4 Suborbital Space Flight

The second Mercury manned suborbital test flight (MR-4), carrying Astronaut Virgil I. Grissom, was made successfully on July 21, 1961. Launched from Cape Canaveral, Florida, at 8:20 am EST, the space capsule followed approximately the same path as the MR-3 flight. Preliminary data from the 16-minute flight indicate that MR-4 reached a peak altitude of about 118 statute miles, a maximum inertial velocity of 5280 mph, and a distance downrange of 303 statute miles.

Several modifications were made in the spacecraft and in the astronaut's duties for the MR-4 flight. To improve visual observation, the two small portholes of earlier capsules were replaced by a trapezoidal window, 19 inches high, 11 inches across the base, and 7½ inches across the top, located directly above the astronaut's head; the new window provides a direct view of the horizon, thus permitting rapid determination of the capsule's attitude, and has reference lines to help the pilot maintain the correct angle for retro-fire. Also, instrument groupings were rearranged on the panel for easier reference; improvements were made in the manual control system to permit more rapid and precise attitude adjustment; and the escape hatch was fitted with explosive bolts for quick emergency egress. Finally, the astronaut was given fewer tasks than were performed during MR-3 to allow more time for observation.

The flight profile for the second manned Mercury flight was virtually the same as for the first. Astronaut Grissom performed his tasks well, maintained voice contact with the ground, and showed no ill effects of flight stresses. He reported by radio that the sky was black, and the sun very bright; a star, later identified as Capella, was also observed. The astronaut could see the southeastern coastline of the U. S. as far north as Cape Hatteras.

While the MR-4 flight itself was highly successful, the spacecraft was lost shortly after landing in the sea when the explosive bolts unexpectedly blew the hatch away; the capsule was flooded and sank in about 17,000 feet of water. Virtually all flight data were telemetered to the ground and are thus available for study, but the film record of the on-board camera was lost with the capsule. One of the recovery helicopters attached a line to the capsule, but the weight of the water inside made it impossible to lift the craft from the sea, and it was cut loose. Astronaut Grissom climbed from the capsule immediately after the hatch blew off and, after swimming several tens of feet in his pressure suit, was picked up by another helicopter. He was landed on the deck of the aircraft carrier USS *Randolph* a few minutes later.

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